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Analysis of the Effectiveness of Sorption and Membrane Technologies and Water Purification Equipment with Increased α-Activity for Domestic Water Supply

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Abstract

Currently, individual systems based on drilling water wells and equipment are more and more often used for domestic water supply. In the mountainous provinces igneous rocks of the ancient origin have a high value of radionuclides which leads to the enrichment of the groundwater with the abovementioned elements. Private users rarely make a water analysis of these elements. The standard values in relation to the parameters of the α and β activity for the use of water for drinking purposes are often exceeded. In connection with this, it is topical to carry out the analysis of methods of purification of water with high values of the α and β activity. Therefore, there is a need of cleaning of the under-ground water from radionuclides. The analysis of the implementation of sorption and different barometric methods of water purification with a high value of α-activity is carried out. It is proved that the most appropriate method is nano-filtration.

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Keywords: under-ground water; α-activity; ultra-filtration; nano-filtration; reversed osmose; sanitary norms

1. Introduction

Currently the population increasingly uses the lack of control in the field of personal water supply of individual dwellings. Especially it is widely distributed in areas with underdeveloped infrastructure of centralized water supply systems. Thus, generally ground water is used which is more pure than the surface one. The chemical composition of the water is not always studied and if studied - only the main indicators. The content of radionuclides in the water

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is practically not studied due to the high cost of the analysis and the unavailability of specialized laboratories to conduct it. At the same time in underground water sources in several regions of Russia there is the presence of naturally occurring radionuclides in concentrations exceeding the maximum permissible limits for drinking water.

Therefore, the evaluation of methods of water purification with high alpha activity available for use by individual water supply is a topical issue and task.

2. Short reference on the origin of under-ground water with increased α-activity

Natural radioactivity of water is determined by the presence of decay products of isotopes of uranium ^{238}U and thorium ^{232}Th in it including radium and radon [5-17, 19-20].

The total α-activity as the amount of radiation of different natural radionuclides is particulate compounds in water which are in different phases. For this reason, the activity of alpha-index correction is difficult as within the standard program of the studies it is impossible to identify the phase of research for finding these substances in water.

Increased concentration of radionuclides is reflected in the radiological program 'Total Alpha Activity' and amounted to 0.66 Bk/kg at a rate of 0.2 Bk/kg [Sanitary Rules and Regulations 2.1.4.1074-01]. The concentration of hardness ions in source water is fixed at 10,7 ± 1,6 mEq/l at admissible 7 mEq/L [Sanitary Rules and Regulations 2.1.4.1074-01].

2.1. Justification Of Purifying Methods

Given the possibility of finding a group of substances causing water alpha activity (uranium, thorium, radium, lead, and polonium) both in the dissolved state and in a colloidal suspension, as well as the inability to guarantee the permanence of separation of substances phases coming from the source four possible water purification methods have been allocated [1-4,18]:

1. *Ultrafiltration*. A cleaning method at a unit with ultrafiltration membranes. Pore size: 0.01 ... 0.1nm. Operating pressure: 2 ... 10 bar. Extraction of suspended solids and part of colloidal ones from water. The salt composition (solute) is not corrected.
2. *Nano-filtration*. A method of cleaning at a unit with nano-filtration membranes. Pore size: 0.001 ... 0.01 mm. Operating pressure: 8 ... 13 atm.

Extraction of suspended and colloidal substances, as well as 60 - 97% of dissolved salts. In the absence of other exceeded indicators and meeting the requirements of the quality of source water for installation of nano-filtration allows getting water of drinking quality in accordance with the Sanitary Rules and Regulations 2.1.4.1074-01.

3. *Reverse osmosis*. Cleaning method at a unit with a back osmotic membrane. Pore size: less than 0.001 microns. Operating pressure: 100 atm.
4. *Sorption*. To analyze the effectiveness of this method a multifunctional sorbent (patent No.2481153) developed by professor G.G. Mikhailov is used.

2.2. Methods Of Study

As part of the tasks set for the tests necessary analytical instrumentation and filtration membrane units of South Ural State University (SUSU) were involved. A water sample for testing was water from f well penetrated the aquifer of granites characterized by significant excess of maximum permissible concentration (MPC) of Sanitary Rules and Regulations 2.1.4.1074-01 in terms of alpha activity - 0.66 Bk/kg at a standard rate of 0.2 Bk/kg. The concentration of hardness ions in the source water is fixed at 10.7 ± 1.6 mg-Eq/l at the admissible 7 mg-Eq/l [Sanitary Rules and Regulations 2.1.4.1074-01] and the value of beta activity of 0.27 Bk/kg at a standard rate of 1.0 Bk/kg.

At the first phase the preparation of source water was carried out: sampling in the volume of 1000 liters and storage in an open reservoir for 3 days prior to the completion of the decay process ^{222}Rn.

Tests included the purification of water at ultrafiltration unit, nano-filtration, reverse osmosis, and sorption unit.

2.3. Results Of Water Purification

The test results were obtained from 4 samples of treated water of volume of 50 liters each and sent for the relevant tests.

1. The result of the water purification at an ultrafiltration unit was a decline of alpha-activity from 0.66 Bk/kg in the source water to 0.53 Bk/kg in the filtrate (with Sanitary Rules and Regulations 21.4.1074-01 of 0.2 Bk/kg) and the decline of beta-activity from 0.27 Bk/kg to 0.24 Bk/kg indicating that the naturally occurring radionuclides causing these indicators are mostly located in the water in a dissolved form. Reduction indicator 'total hardness' is not seen as ultrafiltration membranes do not remove dissolved salts. Thus, ultrafiltration can not be recommended for water purification.

2. The result of water purification at nano-filtration unit was the decline of alpha activity from 0.66 Bk/kg in the source water to 0.09 Bk/kg (with Saniatry Rules and Regulations 2.1.4.1074-01 of 0.2 Bk/kg) in the filtrate and beta activity decline from 0.27 Bk/kg to 0.09 Bk/kg. Reduced alpha activity by 86.4% and beta activity by 66% corresponds to the predicted results and confirms the fact of radionuclides in water in the form of dissolved salts. After the process of purification of water from radiation indicators and the indicator 'total hardness' the water met Sanitary Rules and Regulations 2.1.4.1074-01, and nano-filtration unit can be recommended for water purification.

3. The result of water purification with reverse osmosis was the decrease in alpha activity from 0.66 Bk/kg in the source water to 0.05 Bk/kg (with Sanitary Rules and Regulations 21.4.1074-01 of 0.2 Bk/kg) in the filtrate and beta activity decline from 0.27 Bk/kg to 0.04 Bk/kg. Reduced alpha activity by 92.4% and beta activity by 85.2% reveals deviation from the anticipated results, however, confirms the highest quality of the membrane methods of water purification from dissolved natural radionuclides.

Purification of water in terms of the radiation research program and the indicator 'total hardness' met Sanitary Rules and Regulations 2.1.4.1074-01, and reverse osmosis unit can be recommended for water purification.

However, purified water obtained by reverse osmosis does not satisfy the Sanitary Rules and Regulations 2.1.4.1074-01 in terms of pH, and therefore, this method requires the use of additional water treatment. Furthermore, this method is characteristic of a large amount of concentrate (up to 70% of the source water) which also leads to higher costs for economic exploitation.

4. The result of water purification with the help of sorption was reduction of alpha activity from 2.33 to 0.63 Bk/kg. Results from SUSU laboratory tests on reduction of values of alpha and beta activity in the source water are shown in Tables 'tab. 1-5'.

Table1. Sample Testing on Radiation. Source Water

Measured Parameter	Unit of Measurement	Value	Standard (Sanitary Rules and Regulations 2.1.4.1074-01)
α-activity	Bk/kg	0,66±0,10	0,2
β-activity	Bk/kg	0,27±0,10	1,0

Table 2. Sample Testing on Radiation. Water after Cleaning with Ultrafiltration Unit

Measured Parameter	Unit of Measurement	Value	Standard (Sanitary Rules and Regulations 2.1.4.1074-01)
α-activity	Bk/kg	0,66±0,10	0,2
β-activity	Bk/kg	0,27±0,10	1,0

Table 3. Sample Testing on Radiation. Water after Cleaning with Nano-Filtration Unit

Measured Parameter	Unit of Measurement	Value	Standard (Sanitary Rules and Regulations 2.1.4.1074-01)
α-activity	Bk/kg	0,09±0,06	0,2
β-activity	Bk/kg	0,09±0,04	1,0

Table 4. Sample Testing on Radiation. Water after Cleaning with Reverse Osmosis Unit

Measured Parameter	Unit of Measurement	Value	Standard (Sanitary Rules and Regulations 2.1.4.1074-01)
α-activity	Bk/kg	0,05±0,03	0,2
β-activity	Bk/kg	0,04±0,04	1,0

Table 5. Sample Testing on Radiation. Water after Cleaning the set of sorption*

Measured Parameter	Unit of Measurement	Value	Standard (Sanitary Rules and Regulations 2.1.4.1074-01)
α-activity	Bk/kg	0,63±0,10	0,2
β-activity	Bk/kg	0,16±0,02	1,0

*results are provided by professor G.G. Mikhailov

Thus, testing on water purification were performed which exceeds MAC of alpha activity with the help of bar-abusive and sorption methods. During the tests ultrafiltration, nano-filtration, reverse osmosis, and sorption units were used. As a result of the studies it was established that the most effective method of water purification from natural radionuclides is the method of nano-filtration which showed a decrease of alpha activity by 86.4%. In spite of high effect on this indicator treatment (92.4%) reverse osmosis adjusts the pH to the inadmissible values and, therefore, requires the creation of additional water treatment. Ultrafiltration method was ineffective as this method has reduced water alpha activity by 20% which is not sufficient and water still does not meet the requirements of Sanitary Rules and Regulations 21.4.1074-01. Sorption cleaning method allowed reducing alpha activity by four times but it has not reached the standard indicators.

The most effective and at the same time cost-effective method of water purification from radionuclides is the method of nano-filtration.

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